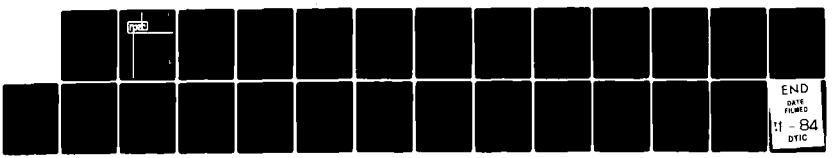
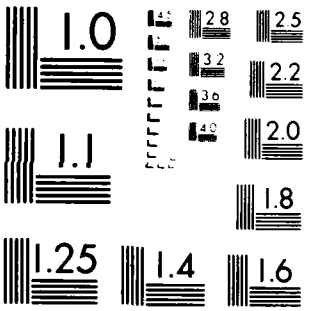
AD-A136 167 PSYCHOBIOLOGICAL CORRELATES OF APTITUDE AMONG NAVY RECRUITS(U) NAVY PERSONNEL RESEARCH AND DEVELOPMENT CENTER SAN DIEGO CA G W LEWIS ET AL. FEB 77 1/1

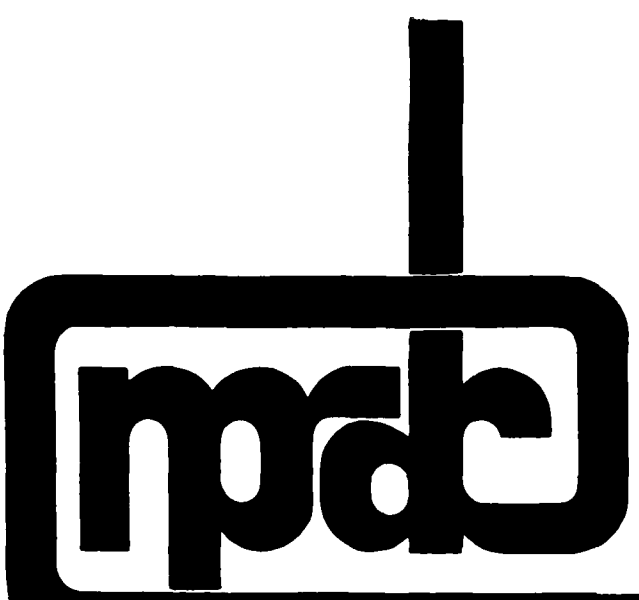
UNCLASSIFIED NPRDC-TN-77-7 F/G 5/9 NL



END
DATE FILMED
11-84
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A



NAVY PERSONNEL RESEARCH AND DEVELOPMENT CENTER · SAN DIEGO, CALIFORNIA 92152

AD-A136267

NPRDC TN 77-7

FEBRUARY 1977

PSYCHOBIOLOGICAL CORRELATES OF APTITUDE AMONG NAVY RECRUITS

DTIC
ELECTE
DEC 2 1 1983
S D
D

DTIC FILE COPY

83 11 07 088

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

Technical Note 77-7 February 1977

PSYCHOBIOLOGICAL CORRELATES OF APTITUDE AMONG NAVY RECRUITS

Gregory W. Lewis
Bernard Rimland

Enoch Callaway, III
Langley Porter Institute

Accession For
NTIS GRA&I
DTIC TAB
Unannounced
Justification
By Per Ltr. on File
Distribution
Availability Codes
Dist | Avail and/or Special
A/1

DTIC COPY INSPECTED 3

Reviewed by
Richard C. Sorenson

Navy Personnel Research and Development Center
San Diego, California 92152

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

FOREWORD

This Technical Note describes research on psychobiological procedures for possible use in personnel screening, classification, and in individualization of instruction conducted in support of the Interlaboratory Independent Research Program.

Appreciation is expressed to Mr. Peter Harris and Mr. Jack Klingelhofer of the University of California Medical Center, San Francisco, for their work on the computer system, and the staff members of the Recruit Evaluation Unit, Naval Training Center, San Diego, whose assistance and cooperation was invaluable.

J. J. CLARKIN
Commanding Officer

SUMMARY

Problem

Paper and pencil tests have been in use many years, and have consistently proven valid in predicting academic performance. They are not effective, however, in predicting certain other important criteria, such as on-job performance. Attempts to improve personnel screening, counseling, and selection by developing different or better paper and pencil tests have not, by and large, proven to be successful. There is a need for new kinds of testing procedures which will supplement the information derived from paper and pencil tests and provide both the Navy and the individuals with an improved understanding of the unique capability of each individual.

Purpose

The purpose of this research was to explore the possibility of using a measure of psychobiological functioning, the visual evoked potential (VEP), as a means of augmenting the personnel information now derived primarily from paper and pencil tests.

Approach

Recently developed computer-based methods of recording and analyzing VEPs were used to test 206 Navy recruits, half of whom had been classified as low aptitude (score of 20-40 centiles on the Armed Forces Qualifying Test (AFQT)) and half, as high aptitude (score 80-99 centiles).

Visual evoked brain potentials were generated by a flashing light stimulus. Computer averaging was used to derive 44 measures of brain wave activity from the eight scalp electrodes. The measures taken were evoked potential amplitude, asymmetry, variance, and latency. Several statistical methods were used to assess the relationship between the VEP variates and the AFQT-based groups.

Results

Significant relationships were found between the brain VEP and the AFQT ($p < .01$). EP variance and latency were the two best psychobiological predictors of AFQT group membership. A discriminant analysis based on factor analytically derived scores proved to be most effective of the statistical methods tried.

Conclusions and Recommendations

The findings are considered encouraging in the search for methods of supplementing information now provided by paper and pencil tests. The techniques developed for fast "production" oriented psychobiological testing are effective. Present plans to follow up the recruits tested and determine the predictive validity of the VEP tests against job performance and job satisfaction criteria should be implemented. The planned evaluation of psychobiological measures as aids in the individualization of instruction should be undertaken.

PRECEDING PAGE BLANK-NOT FILMED

CONTENTS

LIST OF TABLES

FIGURE

PRECEDING PAGE BLANK-NOT FILMED

INTRODUCTION

Problem

Most psychological testing, in both the civilian sector and in the military, is conducted with paper and pencil tests. Conventional tests, while they unquestionably contribute valuable information, are subject to serious shortcomings. Criticisms have been leveled against such tests on the grounds that deliberate falsification is often possible, racial imbalance may be an undesired consequence, and, most serious, their effectiveness in predicting actual on-job performance is low. A large variety of paper and pencil tests have been tried experimentally over the years. None have been found to contribute substantially to the prediction of on-job performance. New kinds of tests are needed which will provide both the Navy and the individual with more complete understanding of the unique capabilities of each individual.

One approach to testing which deserves careful investigation is the use of psychobiological measures. Among other advantages, psychobiological testing represents an objective, hard-to-falsify procedure which is relatively immune to the charges of bias which have been leveled against the traditional screening and selection tests. Further, research on brain function reported within the past decade suggests that in predicting nonacademic criteria, psychobiological tests may be superior to paper and pencil tests. Most paper and pencil tests measure the kinds of logical, sequential, analytical functions served by the dominant (usually left) hemisphere of the brain (Dimond & Beaumont, 1974). Many of the abilities required for effective performance in nonacademic tasks (including most Navy assignments) are best characterized as involving the spatial, judgmental, integrative, simultaneous information-processing skills which appear to be served by the right hemisphere in most people. It seems safe to assume that at least part of the failure of traditional tests to predict real-life performance resides in the heavy demand conventional tests place on left-hemisphere functions. While there is no assurance that psychobiological testing will overcome or compensate for the shortcomings of conventional tests, the prospects are sufficiently promising, and the need for predicting actual job performance so great, that the psychobiological approach seems well worth exploring. During the last decade, a number of laboratories have reported significant correlations between various measures of cognitive function and certain variables yielded by psychobiological testing. Callaway (1975) has extensively reviewed this literature. The present report describes a comparison of "scores" derived from psychobiological analysis with mental ability as measured by the Armed Forces Qualification Test (AFQT), a paper and pencil test used for many years by the military services as a measure of general intellectual capacity.

Purpose

The present study is merely an interim step toward improving our understanding of the relationship between psychobiological measures and performance. While the AFQT can by no means be considered a criterion intrinsically worth predicting, determining its relationship to the psychobiological measures will,

nonetheless, be instructive. In a planned follow-up study, the AFQT and psychobiological measures will be compared in their ability to predict the actual job performance of the recruits tested. It is also planned to evaluate the psychobiological tests as aids in the individualization of instruction, a role in which paper and pencil tests have not yet proven effective.

When first developed, psychobiological measuring techniques were so crude that only rather gross neurological abnormalities had any chance of being detected. Recent developments in computer science and electronics have greatly altered this situation, and highly sophisticated instruments and techniques now are available. The Applied Psychobiology Program of the Navy Personnel Research and Development Center was established to investigate the possibility of employing psychobiological measures and other high-technology methods toward the solution of such Navy personnel problems as recruit screening and classification. The present report is the second in a series describing our efforts. The first described psychobiological measures as predictors of early discharge among marginal Navy recruits (Lewis, Rimland, & Callaway, 1976).

The purpose of this study is to analyze the type of brain-electrical activity known as the evoked potential (EP). Evoked potentials are minute electrical brain waves which are produced by sensory stimulation. They are ordinarily obscured by larger amplitude ongoing electroencephalographic (EEG) activity. Advances in electronics and computer design have made possible the recording and measurement of EPs. The use of the computer to record and average the EP so that it may be seen against the background noise of the EEG has provided a dramatic impetus to research in this field. A major function of our laboratory is the improvement of the methods of testing, so that the operational implementation of our laboratory findings, if implementation is called for, can be readily accomplished.

METHOD

Subjects

Subjects were 206 Caucasian male Navy recruits (basic trainees), who had taken the Armed Forces Qualification Test (AFQT) prior to active duty. They were selected for inclusion in this study on the basis of their AFQT scores. The "Low" group consisted of 103 recruits with AFQT scores ranging between the 20th and 40th centiles (an IQ range of approximately 87 to 96). Recruits scoring below the 20th centile were not accepted into basic training. The "High" group consisted of 103 recruits scoring between the 80 and 99 centiles, corresponding approximately to an IQ range of 113 to 133. The Low group ranged in age from 17.4 to 22.8 years ($\bar{X}$ = 19.2), and the High, from 17.3 to 24.3 years ($\bar{X}$ = 19.6). The AFQT testing preceded the VEP testing by some 7-15 weeks.

Instrumentation

The hardware, software, and visual stimuli are described in detail in an earlier paper in this series (Lewis, Rimland, & Callaway, 1976) and therefore will be described only summarily here.

Data were collected on a portable computer system placed on site at the Navy Training Center facilities, San Diego. The central processing unit was a Data General NOVA 1220 equipped with a floppy disk unit, a small solid state keyboard, an oscilloscope monitor, a flourescent tube for visually stimulating the subject, and an integral eight-channel EEG unit. The EEG electronic unit was optically isolated. It could be calibrated and could measure electrode impedance under computer control. High pass filter settings of 2, .2, and .02 Hz and low pass filter settings of 30 and 100 Hz were available. Visual stimulus was supplied by commerical fluorescent tube with custom-built power supply controlled by the computer. Stimulus duration was 2 msec. It illuminated a homogeneous white rectangle of approximately 7 x 15 inches (18 x 38 cm) placed approximately 1 meter from the subject. Luminance of the target during the flash was approximately 3 foot-lamberts (measured by Gamma Scientific Telephotometer System, Model 2009K).

Definition of EP Measures Obtained

Amplitude

The amplitude was a measure of the average power at each of the electrode sites and was measured in microvolts root mean square (μVrms). At each electrode site, EPs were averaged separately for the first and second 50 flashes. The X-axis (time = 500 msec) for each EP used 250 address locations in the computer. During the averaging, voltages at a particular address (time point) for each EP were obtained. The mean voltage was determined for the entire EP. The deviations from this mean value at each time point were squared, the average of the squared deviations was obtained, and the square root of the average was determined. The value obtained represented the standard deviation of the EP and thus provided, in effect, an approximation of the square root of the average power in microvolts root mean square (μVrms). The μVrms measure

has been found to be correlated with the EP component measures more commonly used (Seals, Naitoh, & Lewis, Note 1). The standard deviation was used rather than the variance in order to keep the units in microvolts instead of watts (Callaway, 1975). An average power value was determined for each of the two sets of 50 flash EPs.

Asymmetry

EP asymmetry is an index of the difference in the evoked voltages (μVrms) measured from homologous sites on the scalp. The more dissimilar the hemispheres in the amplitude of response, the higher the asymmetry values. Four asymmetry values were obtained simultaneously, since EPs were measured at each of the four pairs of left and right hemisphere sites (frontal, central, parietal, occipital). Five asymmetry measures were evaluated, i.e., L-R, (L-R)/(L+R), (L-R)/L,(L-R)/R, L/R; however, the last three measures were deleted after principal component analysis.

Variance

EP variance measures the overall trial to trial variability of EPs. At each light flash all 8 EPs are summed to provide a single EP. Then, for each of the 250 time points a sum and sum of squares are computed so that at the end of 100 flashes, 250 standard deviations can be computed. These are averaged to provide the final measure.

Latency

Latency is defined as the time delay (msec) from the onset of the stimulus to a designated feature of the EP waveform. In this study, EP latency was determined from the onset of the visual stimulus to the first, second, and third positive slope zero-crosses, i.e., approximately 100, 200, and 300 msec respectively to be referred to as L1, L2, L3. Zero-cross was defined as the point where the waveform passed through base line (zero voltage) in the positive direction.

Procedures

The subjects were prepared for recording after they had received brief instruction and had signed voluntary consent forms.

After the technician had cleansed the hair and scalp at the electrode sites with an alcohol-impregnated cotton swab, a Lycra helmet was placed on the subject's head. Lucite bushings, secured to the helmet, held the electrodes in place at the desired recording sites (Jasper, 1958). The electrodes were of the standard EEG recording type (Beckman miniature, 11 mm), each having a clear plastic extension tube attached and filled with electrolytic solution. A small sponge soaked with electrolyte held the solution in the tube and made contact with electrode paste on the scalp. The extension tube minimized slow potential drift, which otherwise would have been picked up at the recording site.

Eight channels of visual evoked potential (VEP) data were acquired from homologous sites on the left and right hemispheres. These were frontal (F3, F4), central (C3, C4), parietal (P3, P4), and occipital (O1, O2). Each channel was referenced to the vertex (Cz). Subject ground was on the midline in the parietal region (Pz).

After all electrodes were in place and the impedance was checked (<5 KΩ), the subject was instructed to observe his real-time EEG activity on the oscilloscope display. He was then instructed to move his jaws, eyebrows, etc., so that he could observe how muscle artifact may contaminate the VEP data. The subject was then seated in a darkened room in alignment with the visual stimulus. A hand-held "time-out" switch was given to the subject which permitted him to suspend all stimulus presentation and analysis operations. He was instructed to press the switch to reject muscle artifact when he had to move, cough, etc. The experimental session was divided into phases A and B.

Phase A--Amplitude, Asymmetry, and Variance

In phase A, the subject observed computer-generated aperiodic flashes in two series of 50 flashes each, while amplitude data were obtained from each of the eight channels referenced to Cz. Band pass was between approximately 2.0 and 30 Hz for this phase. Separate waveforms and amplitude (μVrms) values were recorded for the first and second 50 flashes separately and displayed on the monitor scope. The first 50 flashes will be designated by number 1 and the second 50 by number 2 (e.g., frontal 1, frontal 2). A Polaroid photo was made of the data display.

Phase B--Latency Measures

In phase B, procedures similar to those used by Ertl and Schafer (1969) were used to obtain latency values. Rather than the computer-generated aperiodic flashes used in phase A, the flash was triggered in phase B by the subject's own EEG activity (self-stimulation). Band pass was between approximately .2 and 30 Hz for this phase. The subject's EEG activity between frontal and parietal right hemisphere sites was monitored by computer. When the EEG activity passed through the base line (zero-cross) with a positive-slope, the light was flashed and the subsequent EP was recorded. The reliability of the EP latency measures was increased by taking into account the background EEG activity. Latency values for the 3 zero-crosses were computed (L1, L2, L3) and displayed on the scope monitor along with the analog EP waveform. A Polaroid photo was made to record the data after the latency values had been averaged for 100 flashes.

ANALYSIS AND RESULTS

The basic data included left and right hemisphere amplitude variates from the frontal, central, parietal, and occipital recording sites, first and second series of 50 flashes each (total of 16 amplitude variates). Two measures were used to assess hemispheric asymmetry--L-R, and (L-R)/(L+R). An additional derived measure, 1/(L+R), a single mean variance measure, and three latency measures were also analyzed, providing a total of 44 variates (Table 1).

Because the relationships between paper and pencil tests (AFQT) and VEP measures are poorly understood, several approaches were taken in analyzing the data, including:

- Individual t and F tests were used to determine the relationships between the individual variates and the criterion.

- The data were split randomly into two samples for discriminant analysi with the results from the first (training) sample evaluated on the second (test) sample.

- The data were factor and cluster analyzed, and the ability of the clusters to discriminate the criterion groups was examined.

- Scatterplots of selected variate pairs were prepared by computer, to permit visual inspection of data-criterion relationships.

t and F Tests

Means and standard deviations for each of the variates appear in Table 1. Also included in Table 1 are the t tests of means (204 df) and the variance-ratio F tests (102, 102 df) for the Low and High groups. Although a significant F test renders the t test ambiguous, it was nevertheless thought instructive to present the complete series of t and F tests.

EP variance produced the largest t value ($t = 2.97$, $p < .01$). The second largest t value was obtained for parietal 1 L-R asymmetry ($t = 2.65$, $p < .01$). While the parietal 1 left hemisphere amplitude t value was statistically significant ($t = 2.35$, $p < .02$), the parietal 1 right hemisphere amplitude t value was not ($t = .59$, NS). When these two amplitudes were combined (asymmetry measures), statistically significant t values were obtained for both parietal 1 L-R ($t = 2.65$, $p < .01$) and parietal 1 (L-R)/(L+R) ($t = 2.38$, $p < .02$).

The Low group amplitudes were larger than those of the Highs in six out of eight comparisons for the left hemisphere and four out of eight for the right, although in only two instances were the differences significant (parietal 1 left hemisphere and frontal 1 right hemisphere).

Seventeen of the F ratios in Table 1 are significant at the .05 level or better. Of these, 13 show the standard deviations to be larger for the Low group. This is not suprising, since the Lows are likely to be more heterogenous, as a consequence of including, in all probability, a number with subclinical neurological impairments. The High group also is likely to include unidentified pathological cases which increase its heterogeneity, but to a lesser extent. The differences between the Lows and Highs in EP dispersion may prove helpful in predicting group membership.

Table 1

Means, Standard Deviations and Significance Tests for the Low and High Groups

Variate	Lows (N = 103) $\bar{X}$	Lows (N = 103) SD	Highs (N = 103) $\bar{X}$	Highs (N = 103) SD	Significance Tests $t_{(204)}$	Significance Tests $F_{(102,102)}$
AMPLITUDE						
Frontal 1 LH	2.260	1.071	2.066	.795	1.47	1.81***
Frontal 2 LH	2.157	1.284	2.123	1.047	.21	1.50*
Central 1 LH	1.478	.579	1.365	.524	1.47	1.22
Central 2 LH	1.386	.560	1.330	.482	.76	1.34
Parietal 1 LH	2.094	.751	1.870	.604	2.35**	1.54*
Parietal 2 LH	1.943	.691	1.891	.699	- .53	1.02
Occipital 1 LH	2.983	1.180	3.153	1.271	.99	1.16
Occipital 2 LH	3.380	1.403	3.515	1.348	- .70	1.08
Frontal 1 RH	2.229	.890	2.004	.708	2.00*	1.58**
Frontal 2 RH	2.163	.962	2.146	1.145	- .11	1.41*
Central 1 RH	1.642	.741	1.538	.540	1.14	1.88***
Central 2 RH	1.458	.681	1.384	.598	.82	1.29
Parietal 1 RH	2.051	.752	2.118	.865	.59	1.32
Parietal 2 RH	1.952	.733	2.105	.920	1.31	1.57**
Occipital 1 RH	3.308	1.127	3.470	1.142	1.02	1.02
Occipital 2 RH	3.533	1.507	3.707	1.350	- .87	1.24
DERIVED AMPLITUDE MEASURES						
Frontal 1 L-R	.033	1.127	.061	.741	- .20	2.31***
Frontal 2 L-R	- .007	.986	- .002	.997	.04	1.02
Central 1 L-R	- .163	.779	- .173	.474	.11	2.69***
Central 2 L-R	- .074	.669	- .053	.576	- .23	1.34
Parietal 1 L-R	.042	.876	- .249	.689	2.65***	1.61***
Parietal 2 L-R	- .009	.752	- .214	.653	2.09*	1.32
Occipital 1 L-R	- .324	.881	- .316	.863	- .06	1.04
Occipital 2 L-R	- .152	.751	- .192	.781	- .37	1.08
Frontal 1 (L-R)/(L+R)	.000	.195	.005	.176	- .21	1.22
Frontal 2 "	- .021	.195	.001	.207	.79	1.12
Central 1 "	- .045	.191	- .067	.171	.87	1.24
Central 2 "	- .019	.176	- .009	.180	.41	1.04
Parietal 1 "	.015	.187	- .044	.173	2.38**	1.15
Parietal 2 "	- .001	.176	- .042	.146	1.81	1.44*
Occipital 1 "	- .048	.147	- .050	.176	- .05	1.42*
Occipital 2 "	- .019	.100	- .024	.124	- .30	1.53*
Frontal 1 I/(L+R)	.256	.104	.271	.101	-1.02	1.05
Frontal 2 "	.272	.105	.273	.101	- .08	1.07
Central 1 "	.360	.127	.380	.134	1.08	1.11
Central 2 "	.398	.143	.412	.145	.69	1.02
Parietal 1 "	.268	.091	.276	.083	- .64	1.18
Parietal 2 "	.285	.097	.277	.084	.64	1.31
Occipital 1 "	.180	.064	.172	.067	- .81	1.09
Occipital 2 "	.167	.070	.155	.057	1.35	1.53*
VARIANCE	8.285	2.034	7.564	1.381	2.97***	2.16***
LATENCY						
L1	91.757	15.109	89.145	12.551	1.34	1.44*
L2	189.097	27.281	185.475	23.233	1.02	1.37
L3	289.834	41.337	283.301	34.368	1.23	1.44*

*** $p < .01$
** $p < .02$
* $p < .05$

The standard deviations for the Lows exceeded that for the Highs in six of the eight left-hemisphere amplitude comparisons, three significantly. The right hemisphere comparisons found the Low group standard deviations to exceed the Highs in four of the eight comparisons, two significantly.

Discriminant Analysis

Stepwise Multivariate Discriminant Analysis (DA) (Dixon, 1973) was applied to the data. The 44 variates listed in Table 1 were used in the DA analysis.

For the DA, the two groups were each randomly divided into two subsamples which will be called "training" and "test" (cross validation) sets. The results of training/test procedures are found in Table 2. The variate which contributed most to between-group differentiation for the training set (Lows N = 53, Highs N = 52) was EP variance ($F(1,103) = 14.71$, $p < .01$). However, EP variance classified only 47 percent of the recruits correctly in the test set (Lows N = 50, Highs N = 51), ($X^2 = .14$, NS). A latency component (L1) was entered at step 2 ($F(1,102) = 6.81$, $p < .02$). This was the first of three zero-cross values obtained during the self-stimulation session (B). Test set classification increased to 54 percent ($X^2 = 1.24$, NS). The occipital 2 1/(L+R) variate was entered at step 3 ($F(1,101) = 4.54$, $p < .05$). Test set classification increased to 56 percent ($X^2 = 2.30$, NS). Parietal 1 left hemisphere amplitude entered the DA at step 4 and allowed 59 percent of the test set to be correctly classified ($X^2 = 4.51$, $p < .05$).

Factor Analysis

To reduce the variate set to a smaller and more reliable one, the 16 amplitude, the variance, and the three latency measures were subjected to factor analysis (FA) (Dixon, 1973). John and Thatcher (1976) have reported the FA approach helpful in classification via discriminant analysis. These investigators, however, used several hundred variates in their analyses. Results for the varimax rotation FA appear in Table 3.

Five factors exceeded an eigenvalue of 1.0 and accounted for a total of 73 percent of the variance. The factors may be labeled (1) central amplitude and variance, (2) latency, (3) occipital amplitude, (4) frontal left hemisphere amplitude and parietal right hemisphere amplitude, and (5) frontal right and parietal left amplitudes. For each recruit, five factor scores were calculated for use in the next step of the analyses.

Factor-Discriminant Analysis

The five factor scores derived above were input to DA, using the same training and test sets as before. The results of this analysis appear in Table 4.

Table 2

Discriminant Analysis Summary
Basic Data Input for Low vs. High Group Comparisons

Step Number	Variate	F	Correct Classification[a] Training Low (N = 53)	Training High (N = 52)	Training Total (N = 105)	Test Low (N = 50)	Test High (N = 51)	Test Total (N = 101)	Chi-Square Training (N = 105)	Chi-Square Test (N = 101)
1	EP Variance (μVrms)	14.71***	57 (30)	73 (38)	65 (68)	26 (13)	69 (35)	47 (48)	10.76***	.14
2	L1 Latency (msec)	6.81**	60 (32)	67 (35)	64 (67)	40 (20)	69 (35)	54 (55)	9.23***	1.24
3	Occipital 2 1/(L+R)	4.54*	62 (33)	71 (37)	67 (70)	44 (22)	69 (35)	56 (57)	13.20***	2.30
4	Parietal 1 LH (μVrms)	2.84	64 (34)	67 (35)	66 (69)	48 (24)	71 (36)	59 (60)	11.70***	4.51*

[a]Top entry in each cell is percentage correctly classified; lower entry, in parens, is frequency.

***p < .01
**p < .02
*p < .05

Table 3

Varimax Rotated Factor Matrix of Visually Evoked Potentials

Variates	Factors				
	1	2	3	4	5
AMPLITUDE					
Frontal 1 LH	.28	.12	.13	-.71	.27
Frontal 2 LH	.00	.08	.02	-.88	.28
Central 1 LH	.62	.04	.18	-.09	.44
Central 2 LH	.54	.05	.18	-.21	.47
Parietal 1 LH	.46	.09	.40	-.18	.57
Parietal 2 LH	.20	.09	.62	-.26	.48
Occipital 1 LH	.29	.01	.71	-.14	.07
Occipital 2 LH	.15	.04	.83	-.06	.34
Frontal 1 RH	.39	.17	.27	-.12	.58
Frontal 2 RH	.04	.15	.18	-.43	.68
Central 1 RH	.81	.13	.09	-.10	.14
Central 2 RH	.77	.17	.21	-.11	-.04
Parietal 1 RH	.37	-.01	.39	-.63	-.05
Parietal 2 RH	.13	.02	.50	-.60	-.25
Occipital 1 RH	.09	.03	.82	-.19	-.12
Occipital 2 RH	.08	.02	.88	-.03	.21
VARIANCE	.54	.06	.24	-.29	.27
LATENCY					
L1	-.07	-.96	-.05	.01	-.04
L2	-.07	-.99	.00	.06	-.05
L3	-.06	-.97	-.02	.06	-.06
Proportion of Variance	.374	.141	.087	.074	.054
Cumulative variance	.374	.515	.602	.676	.730

Underlined factor weights > .50

Table 3

Varimax Rotated Factor Matrix of Visually Evoked Potentials

Variates	Factors				
	1	2	3	4	5
AMPLITUDE					
Frontal 1 LH	.28	.12	.13	-.71	.27
Frontal 2 LH	.00	.08	.02	-.88	.28
Central 1 LH	.62	.04	.18	-.09	.44
Central 2 LH	.54	.05	.18	-.21	.47
Parietal 1 LH	.46	.09	.40	-.18	.57
Parietal 2 LH	.20	.09	.62	-.26	.48
Occipital 1 LH	.29	.01	.71	-.14	.07
Occipital 2 LH	.15	.04	.83	-.06	.34
Frontal 1 RH	.39	.17	.27	-.12	.58
Frontal 2 RH	.04	.15	.18	-.43	.68
Central 1 RH	.81	.13	.09	-.10	.14
Central 2 RH	.77	.17	.21	-.11	-.04
Parietal 1 RH	.37	-.01	.39	-.63	-.05
Parietal 2 RH	.13	.02	.50	-.60	-.25
Occipital 1 RH	.09	.03	.82	-.19	-.12
Occipital 2 RH	.08	.02	.88	-.03	.21
VARIANCE	.54	.06	.24	-.29	.27
LATENCY					
L1	-.07	-.96	-.05	.01	-.04
L2	-.07	-.99	.00	.06	-.05
L3	-.06	-.97	-.02	.06	-.06
Proportion of Variance	.374	.141	.087	.074	.054
Cumulative variance	.374	.515	.602	.676	.730

Underlined factor weights > .50

Table 4

Discriminant Analysis Summary
Factor Score Input for Low vs. High Group Comparisons

Step Number	Variate	F	Correct Classification[a] Training Low (N = 53)	Training High (N = 52)	Training Total (N = 105)	Test Low (N = 50)	Test High (N = 51)	Test Total (N = 101)	Chi-Square Training (N = 105)	Chi-Square Test (N = 101)
1	Factor 2 Latency	3.93[b]	60 (32)	62 (32)	61 (64)	72 (36)	33 (17)	52 (53)	5.96*	.64
2	Factor 5 Frontal RH Parietal LH	3.61	51 (27)	62 (32)	56 (59)	76 (38)	39 (20)	57 (58)	2.20	3.45
3	Factor 1 Central RH, LH Variance	2.28	62 (33)	63 (33)	63 (66)	68 (34)	61 (31)	64 (65)	8.02**	9.61**

[a]Top entry in each cell is percentage correctly classified; lower entry, in parens, is frequency.

[b]$F_{1,100} = 3.94$, $p < .05$

**$p < .01$
*$p < .02$

Factor 2 (latency) accounted for the greatest amount of between-group discrimination and was thus entered at step 1 ($F(1,103) = 3.93$). This F value was just at or below the $p < .05$ significance level ($F(1,100) = 3.94$, $p < .05$). A total of 52 percent of the test set recruits were correctly classified ($X^2 = .64$, NS). Factor 5 (frontal right and parietal left amplitudes) was entered at step 2 ($F(1,102) = 3.61$, NS) and permitted 57 percent of the test set to be correctly classified ($X^2 = 3.45$, NS). At step 3, factor 1 (central amplitudes and variance) was entered ($F(1,101) = 2.28$, NS), which increased the test set classification to 64 percent ($X^2 = 9.61$, $p < .01$). Classification decreased after step 3.

Factor--Cluster Analysis

For this approach, two cluster analyses were performed on the data from all 206 recruits, one using the same 20 variates input to factor analysis, the other using the five factor scores only. When the 20 basic data variates were input directly into the clustering program, NORMIX (Wolfe, 1970), no statistically significant relationship was found between the Low and High groups and the resulting cluster structure (X^2 = NS). However, when the factor scores were input, three clusters were derived which were found to be significantly related to the Low-High criterion. Table 5 shows the classification of the Low and High groups into each of the three cluster types. Chi-square analysis for the first two clusters was statistically significant ($X^2 = 4.48$, $p < .05$). The third cluster appears to be a residual.

Table 5

Cluster Matrix for the Low and High Groups

Group	Cluster Type 1	2	3
Lows	25	76	2
Highs	39	62	2

Scatterplots

Statistical analysis, while of undoubted value, by no means exhausts the informational value of a data set. To supplement the information provided by the statistical analysis, a series of bivariate scatterplots was run to permit visual inspection. Each variate was studied in at least one plot, and some of the more important variates were paired with several others. Figure 1, a sample scatterplot, depicts the relationship between variance and parietal 1 (L-R)/(L+R). Figure 1 is presented here for purposes of illustration, rather than to establish a position with regard to the value of the particular 2-variate combination it depicts. It is of interest, nevertheless, that the joint use of these variates would appear to be very effective in screening out the Lows (11 of 15 in the upper left quadrant) or identifying the Highs (72 of 118 in the lower left quadrant). Chi-square for these two quadrants is significant ($X^2 = 7.99$, $p < .01$). The homogeneity of the Highs, as compared to the Lows, is noteworthy.

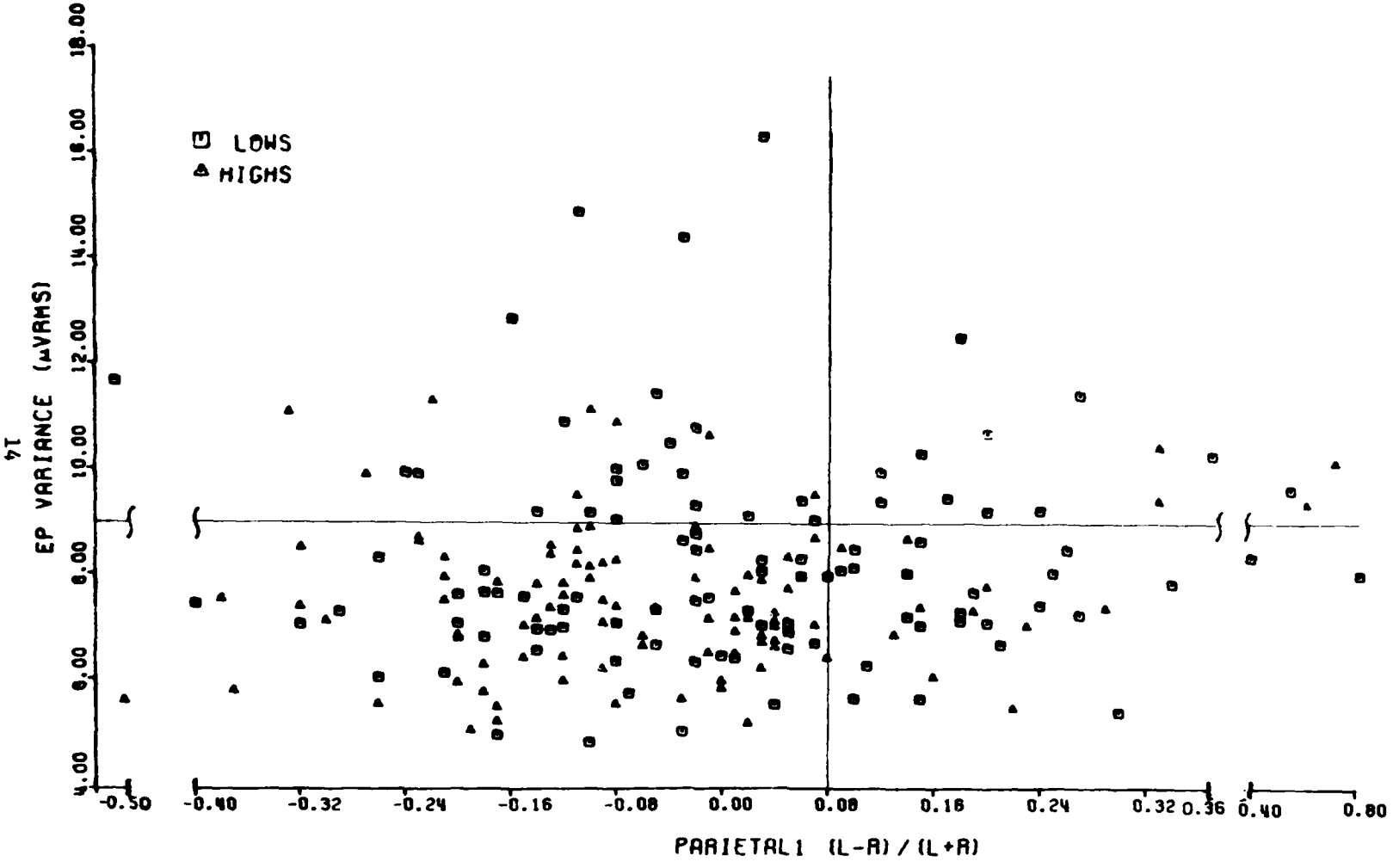


Figure 1. Scatterplot showing relationship between Parietal 1 (L-R)/(L+R), EP Variance and Criterion

The scatterplot analysis was used, in part, to find nonlinear relationships between variate pairs. None were evident from first inspection, but this phase of the work is continuing.

DISCUSSION

The present study was intended to be exploratory, rather than definitive. It was intended to probe the problem area rather than to provide firm conclusions about it. At this stage the problem area is too new, and there are far too many unknowns, for definitive answers to emerge from research. Nevertheless, there are a number of observations that can be made with reasonable confidence, and which fit into the extensive literature which has developed in this field.

Our choice of amplitude, asymmetry, variance, and latency as the measures to be investigated was based upon such findings as Galin and Ellis' (1975) report that EP asymmetry varies as a function of subject involvement in a verbal as opposed to a spatial task. Asymmetry EP measures have also been found to vary as a function of presenting words vs. nonsense patterns (Buchsbaum & Fedio, 1969), phonemes vs. pure tones (Morrell & Salamy, 1971), and spatial stimuli (Vella, Butler, & Glass, 1972). Relationships between EP and EEG asymmetry and ability have been found for bright vs. dull children (Rhodes, Dustman, & Beck, 1969; Lairy, Remond, Rieger, & Lesevre, 1969) and for normal vs. retardate children (Richlin, Weisinger, Weinstein, Giannini, & Morgenstern, 1971).

EP variability has been found to be related to age (Callaway & Halliday, 1973), visual-motor integration (Callaway & Stone, 1969), and cognitive ability (Stone, 1968; Callaway & Stone, 1969).

Latency of the EP has been found to be inversely related to mental ability (Chalke & Ertl, 1965; Ertl & Schafer, 1969; Shucard & Horn, 1972). Other investigators have failed to confirm these results (e.g., Dustman & Beck, 1972; Shagass, 1972).

In general, our results seem promising. We have found several significant relationships, and confirmed some relationships reported by others, between certain VEP measures and mental ability, as defined by a paper and pencil test (the AFQT). The finding of no relationship would have been disappointing, because the AFQT has been found to be related to a number of criteria of interest (Maier & Fuchs, 1972). The finding of a high degree of relationship would also be unwelcome, because it is well established that existing paper and pencil tests do not predict on-job performance criteria (e.g., Ghiselli, 1966).

Of the measures evaluated in the present study, EP variance appeared most effective in discriminating the Low and High groups. The High group showed smaller variance. Other studies have also reported large EP variance to be more common in groups of individuals functioning at low cognitive levels than in high functioning groups, including young children, the elderly, and schizophrenics. Caution appears to be in order, however, for some believe that large variance is not a sign of low ability per se, but instead merely reflects poor cooperation, excessive eye motion, and low motivation. Shagass (1972) has noted that, in schizophrenics, variance may be diminished in the early stages of the EP and enlarged in the later stages, perhaps reflecting a disorder of sensory preprocessing. Unfortunately, our present design did not distinguish the stages of EP variance--a shortcoming readily correctible in later studies.

The variate next in importance was latency. In order to obviate the effects of ongoing EEG activity on our latency measures, we had the EP triggered by the EEG itself (on a positive zero-cross). While this procedure had the desired effect, it concommitantly permitted the EEG background frequency to influence latency as measured. This may account for the rather low relationship observed between latency and AFQT. There has been a vigorous controversy over the relationship between latency and conventionally measured mental ability, following Chalke and Ertl's (1965) original report that short latency indicated high IQ. Callaway (1975) has recently reviewed the subject. In general, our findings are consistent with Ertl's, although the relationship between latency and ability in our study was not high, and the value of latency as a predictor of group membership varied as a function of the statistical method used.

A major purpose of the present study was to compare various modes of data analysis. The variates derived from VEP analysis are so different from those found in traditional paper and pencil studies in their statistical properties that few assumptions about transferability of analytical techniques can be made with assurance. It was therefore of special interest to find that the various methods did in fact prove to be differentially effective.

The combination of factor analysis and discriminant analysis seemed to be especially effective. John and Thatcher (1976) have reported good results with a similar approach. The present study used only a single measure of aptitude, AFQT score. The AFQT consists of verbal, spatial, mechanical, and numerical items, but subtest scores are not recorded. Since the relationship between EP measures and paper and pencil test scores appears to depend on the content of the test (Everhart, China, & Auger, 1974), it is surprising that our factor analysis did so well with a complex test. Street, Perry, and Cunningham (1976) found in their factor analysis, as we did, that the various EP measures tend to form separate cohesive factors. The multivariate approach was reported to be helpful by Perry, McCoy, Cunningham, Falgout, and Street (1976) in describing VEP-ability relationships.

Although the present attempt to evaluate different statistical approaches toward treating psychobiological measures yielded encouraging findings, our efforts thus far must be considered preliminary. It is planned to explore the matter more deeply, using a series of subtest scores and trying principal component and discriminant analysis in combination.

CONCLUSIONS AND RECOMMENDATIONS

This study has demonstrated several significant relationships between certain psychobiological measures and a traditional measure of aptitude, the AFQT. Evoked potential variance and latency were the two most predictive VEP measures. While the AFQT is merely an intermediate criterion--there is no practical reason for wanting to predict AFQT scores--the present findings offer encouragement that our ultimate goal, improved prediction of on-job performance, may be achieved. Follow-up studies in which actual job performance and job satisfaction will be the criteria are in progress, using as subjects many of the same men, tested as recruits, who were utilized in the present study. It is also planned to evaluate psychobiological tests as aids in the individualization of instruction, a function that paper and pencil tests have proven unable to perform. Such individualization has been looked upon as a promising means of reducing training costs.

The present study also demonstrated the feasibility of large-scale psychobiological testing with a fast-paced "production" orientation, as opposed to the usual more slowly paced clinical or experimental laboratory orientation. With practice and experience, the technician was able to cut total time per subject down to approximately 10 minutes, 7 for affixing and removing electrodes and 3 for testing. If technology can provide induction electrodes that can be placed near the scalp rather than in direct contact with it, the rate of testing may be increased by a factor of two or three.

Progress made to date warrants continuation of research efforts aimed at improving psychobiological testing technology and data analysis methods, while also continuing the long-term follow-up studies designed to evaluate the effectiveness of such tests as predictors of the future effectiveness and the future job satisfaction of naval personnel.

REFERENCES

Buchsbaum, M., & Fedio, P. Visual information and evoked responses from the left and right hemispheres. Electroencephalography and Clinical Neurophysiology, 1969, 26, 266-272.

Callaway, E. Brain electrical potentials and individual psychological differences. New York: Grune & Stratton, 1975.

Callaway, E., & Halliday, R. A. Evoked potential variability: Effects of age, amplitude, and methods of measurement. Electroencephalography and Clinical Neurophysiology, 1973, 34, 125-133.

Callaway, E., & Stone, G. C. Evoked response methods for the study of intelligence. Agressologie, 1969, 10, 535-539.

Chalke, F. C. R., & Ertl, J. P. Evoked potentials and intelligence. Life Sciences, 1965, 4, 1319-1322.

Dimond, S. J., & Beaumont, J. G. (Eds.). Hemispheric function in the human brain. New York: John Wiley, 1974.

Dixon, W. J. (Ed.). BMD computer programs. Los Angeles: University of California Press, 1973.

Dustman, R. E., & Beck, E. C. Relations of intelligence to visually evoked responses. Electroencephalography and Clinical Neurophysiology, 1972, 33, 254.

Ertl, J. P., & Schafer, E. W. P. Brain response correlates of psychometric intelligence. Nature, 1969, 223, 421-422.

Everhart, J. D., China, C. L., & Auger, R. A. Measures of EEG and verbal intelligence: An inverse relationship. Physiological Psychology, 1974, 2, 374-378.

Galin, D., & Ellis, R. R. Asymmetry in evoked potentials as an index of lateralized cognitive processes: Relation to EEG alpha asymmetry. Neuropsychologica, 1975, 13, 45-50.

Ghiselli, E. E. The validity of occupational aptitude tests. New York: John Wiley, 1966.

Jasper, H. The ten twenty electrode system of the International Federation. Electroencephalography and Clinical Neurophysiology, 1958, 10, 371-375.

John, E. R., & Thatcher, R. Functional neuroscience, Vol. II. New Jersey: L. Erlbaum Associates. In press, 1976.

Lairy, G. C., Remond, A., Rieger, H., & Lesevre, N. The alpha average, III: Clincial application in children. Electroencephalography and Clinical Neurophysiology, 1969, 26, 453-467.

Lewis, G. W., Rimland, B., & Callaway, E. Psychobiological predictors of success in a Navy remedial reading program (TR 77-13). San Diego: Navy Personnel Research and Development Center, 1976.

Maier, M., & Fuchs, E. F. Effectiveness of selection and classification testing (TR 1179). Washington, D.C.: Army Behavior and Systems Research Laboratory, 1972.

Morrell, L., & Salamy, J. G. Hemispheric asymmetry of electrocortical responses to speech stimuli. Science, 1971, 174, 164-166.

Perry, N. W., Jr., McCoy, J. G., Cunningham, W. R., Falgout, J. C., & Street, W. J. Multivariate visual evoked response correlates of intelligence. Psychophysiology, 1976, 13, 323-329.

Rhodes, L. E., Dustman, R. E., & Beck, E. C. The visual evoked response: A comparison of bright and dull children. Electroencephalography and Clinical Neurophysiology, 1969, 27, 364-372.

Richlin, M., Weisinger, M., Weinstein, S., Giannini, M., & Morgenstern, M. Interhemispheric asymmetries of evoked cortical responses in retarded and normal children. Cortex, 1971, 7, 98-105.

Shagass, C. Evoked brain potentials in psychiatry. New York: Plenum Press, 1972.

Shucard, D. W., & Horn, J. L. Evoked cortical potentials and measurement of human abilities. Journal of Comparative and Physiological Psychology, 1972, 78, 59-68.

Stone, G. E. Temporal properties in cognitive processing of the child. Paper presented at symposium on "Brain Function, Cognitive Performance, and the Developing Child," at the meetings of the American Psychological Association, San Francisco, California, September, 1968.

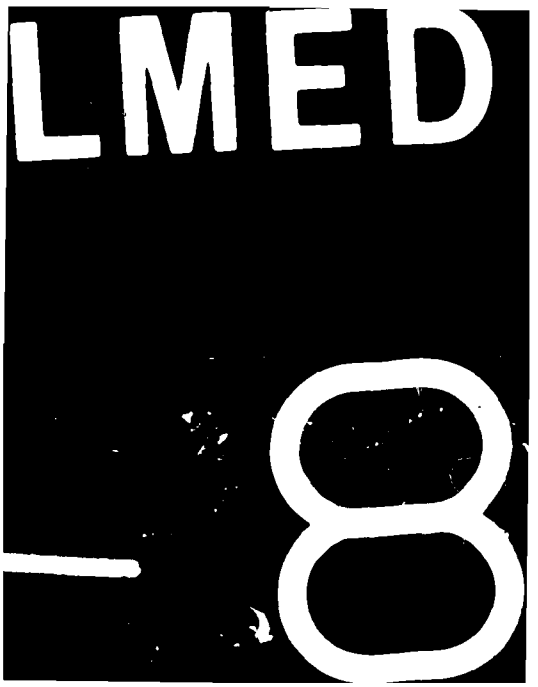
Street, W. J., Perry, N. W., Jr., & Cunningham, W. R. A factor analysis of visual evoked responses. Psychophysiology, 1976, 13, 352-356.

Vella, E. J., Butler, S. R., & Glass, A. Electrical correlates of right hemisphere function. Nature New Biology, 1972, 236, 125-126.

Wolfe, J. H. Pattern clustering by multivariate mixture analysis. Multivariate Behavioral Research, 1970, 5, 329-350.

REFERENCE NOTE

1. Seales, D., Naitoh, P., & Lewis, G. A comparison of RMS and peak-to-peak measures of the somatosensory evoked potential. Naval Health Research Center report in preparation.


LMED
8